FUNCTION REALLOCATION AND SIGNALLING SUPPORT FOR FUTURE NETWORK EVOLUTION

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ABSTRACT

This paper gives the definition of function re-allocation concept in a reconfiguration system. Due to the complexity of the function re-allocation concept which covers the radio subsystem and the O&M subsystem, we dimension the term for easy analysis.

At the radio sub-system dimension, we identify the need of allocate some RNC function to the base station according to the spectrum efficiency reason, the cost and the reaction accuracy. Two typical examples are given: the smart base station which is able to deal with the local radio resource autonomously, and the HSDPA as an evolution path of the 3GPP system. To show spectrum efficiency improvement, two types of scheduling algorithms are compared, i.e., the time scheduling and the code scheduling. The MAC-HS option supported by the HSDPA is the time scheduling mechanism, which requires most of the function being located at the base station.

At the O&M sub-system dimension, we identify the complexity of the O&M system w.r.t. the reconfiguration parameters. According to the correlation between the controlled parameter and the involving function, we are able to distribute the element management and the network management function into several entities, which are able to establish peer to peer communication, to identify the most suitable entity for controlling the reconfiguration. The trends we analysed for the O&M system evolution is the open interface and the peer to peer communication at the O&M system. When such system emerges, the ontology concept is a good candidate. Such trends are also aligned with the Telecommunication management forum visions.

1. INTRODUCTION

Due to the limited capabilities or efficiencies given by the current wireless telecommunication, evolution of the network architecture directly triggered by the re-specification of the involving network elements is under discussion. The conventional functions defined in the legacy entities will be temporarily reallocated to other more suitable entities. In order to support such function- reallocation without noticeable degradation of the system performance, necessary supporting entities are needed in the evolving system.

Conceptually, the following key parameters are the driving reasons for the discussion of function reallocation:

- Efficiency of the existing interfaces
- Efficiency of the reactivity in the control loop
- Delay due to long signalling path
- Cost due to capacity enhancement based on the conventional function allocation
- Flexibility and scalability of new RAT (*Radio Access Technology*) integration

To have a deeper study on the complicated function reallocation study, we dimension the function reallocation according to the following cases:

- Subsystems: radio subsystem and O&M subsystem
- Time scale: short term (temporary) and long term (permanent)

2. FUNCTION REALLOCATION IN THE RADIO SUBSYSTEM

2.1 RAN evolution trends

We have to introduce evolving paths to the current telecommunication network. We based on the de-facto deployed cellular network- UMTS as a good study case to discuss the possible solutions to the above mentioned problems. Guidelines to the solutions are listed as the following:

- Lower latency at RAN
- Increase of spectral efficiency, increase of peak/average throughput
- Decrease of cost per bit including transmission
- IP based transport introduction
- Joint Radio Resource Management (JRRM) with high resource utilization
- Backward Compatibility
- Smooth further midterm improvements
- Flexible bandwidth allocations (900, 1800, 2,6GHz)
- Flexible baseband bandwidths (1.25MHz, 2,5 MHz, 5MHz, 10MHz, 15MHz, 20 MHz)
- Asynchronous system
- Avoidance of Soft HO
- Move most radio Protocols towards base station
- Reuse defined Control Plane, but simplification as much as possible
- Fast market introduction
- Protection of investment

2.2 HSDPA experience

Generally, UMTS uses two types of resource allocation schemes for the involving radio links, the time multiplexing scheme using scheduling algorithms and the continuous transmission of all link using code division. In the following, we compare these two schemes w.r.t. the throughput. To have a fair comparison, the same transmission power, the same number of users and the same traffic demands are assumed.

Continuous Transmission Using Code Division

Suppose user i demands *Signal to Noise Ratio* (SNR) γ_i at the baseband symbol level. In order to fulfil the reception quality (*Bit Error Rate*), the real SIR must be greater or equal to γ_i. Since user data symbol rate R_{S_i} and user bit rate R_i after coding in bps for user i have a fixed relationship as $R_{Si} = R_i / \log_2^M$, with M the maximum number of possible modulated symbols for user data channel, we focus on the symbol rate for performance comparison. Considering the spreading gain given by the direct spreading, we obtain

$$\frac{W}{R_{Si}} \frac{A_i \phi_i P_T}{I_i + \beta(1-\phi_i) A_i P_T + N} \geq \gamma_i \qquad (1)$$

where, W is the bandwidth over which the modulated signal is spread; A_i denotes the signal attenuation from the base station to user i; $\phi_i P_T$ is the portion of power that user i receives, in other words, ϕ_i is the portion of radio resource it obtains from the resource shared system; β is the orthogonality factor modelling the impact of intra-cell interference; I_i is interference from the neighbour cells; N presents noise power. The maximum data symbol throughput R_{D,M_i} for user i is obtained when the *Equilibrium* in Equation (1) holds. It can be derived as

$$R_{D,M_i} = \frac{W}{\gamma_i} \frac{A_i \phi_i P_T}{I_i + \beta(1-\phi_i) A_i P_T + N} \qquad (2)$$

Scheduled Transmission Using Time Multiplexing

If users are served alternatively using different time intervals, we can assume for user i during the observing time interval $(t, t+\Delta t)$, $\phi_i \Delta t$ time period is assigned; the other $(1-\phi_i)\Delta t$ time period is used by other users when user i is waiting. It is assumed that all the involved links have radio access during Δt. During the period of $\phi_i \Delta t$, only user i receives the power P_T assigned by the base station. The maximum user data symbol throughput is therefore:

$$R_{S,M_i} = \frac{W}{\gamma_i} \frac{A_i P_T}{I_i + N} \cdot \phi_i \Delta t \Big/ \Delta t = \frac{W}{\gamma_i} \frac{A_i P_T}{I_i + N} \cdot \phi_i \qquad (3)$$

By comparing Equation (2) and (3), we can easily see the benefit of a time sharing system from the throughput viewpoint as $R_{S,M_i} \geq R_{D,M_i}$. The higher the impact of the intra-cell interference is, the higher is the advantage of the time sharing system, e.g., DSCH. It is obvious that, if the system allows higher modulation schemes for both dedicated channels and shared channel, the benefit of using time sharing system is still valid. For the HSDPA channel, the shortest scheduling time is set to 2ms, with this fine time scale, the system can serve the user with the best channel following the latest *Channel State Information* (CSI).

2.3 Scheduling by the Base Station

In Release 99 and Release 4 of 3GPP specifications, all management of radio resources is performed at the *controlling RNC* (CRNC). And DSCH was the only shared channel in the downlink. However, due to the latencies across the Iub interface between the RNC and base station, and RRC connections from the RNC to the terminal, CRNC cannot accurately manage resource allocation based on the up-to-date CSI. In HSDPA, the CRNC allocates a block of *High Speed DSCH* (HS-DSCH) resources (code tree and transmit power) to the base station that the base station is allowed to autonomously allocate resources between terminals on a dynamic basis. Since there exists only the Uu interface between base station and terminal, the base station can collect CSI from the terminals by means of fast signalling from the physical layer and then perform fast HS-DSCH allocation to terminals. HSDPA adopts advanced adaptive *Modulation and Coding Scheme* (MCS). Upon each radio access instance of a mobile terminal, the base station is able to optimise its transmission format according to the instantaneous radio channel conditions. The terminal sends to the base station an indication of the radio link quality using the CQI (*Channel Quality Indicator*). Based on this, the base station can adapt the MSC in terms of *Adaptive Modulation and Coding* (AMC), where the modulation schemes are changeable between QPSK and 16QAM and coding schemes can be adjusted through amount of puncturing applied to turbo coded data by means of varying the amount of data information transmitted in a TTI, i.e., 2ms [1].

During the TTI period, the selected coding rate and modulation format remain constant. In addition, the transmission power of the HS-DSCH is kept at a constant level and the coding and modulation format is chosen to maximise throughput to the terminal. Increasing the coding rate or moving from QPSK to 16QAM increases the size of the transport block that can be sent during the TTI.

The link adaptation scheme in HSDPA is extended by the multiple-code transmission option. In good channel condition, base station can exploit multi-codes for a user in order to reach optimum overall throughput.

3. SMART BASE STATION CONCEPT

Further intelligence can be introduced to base station extended from the trends given by HSDPA. Under this philosophy, simplification of the UTRAN architecture and consequential reduction of the signalling procedures and protocols are foreseen. Another motivation is given by the enhancement of the peak/average data throughput and the minimisation of the roundtrip delay and the setup times. Furthermore, it is expected to obtain a simplified and unified transport. For that purpose the introduction of IP is a possible solution. In the following, we introduce a possible solution to the evolving network.

The deployment overlay assumes the legacy base stations as well their associated RNCs having been deployed by the operator, Smart base station can be considered as an overlay, i.e., added network elements to the existing network infrastructure. For simplicity reason, we firstly envisage the connectivity from the smart base station to the core network through IP based core network; whether the overlay from circuit switched services through the packet oriented smart base station or not is left as an implementation issue w.r.t. the operator deployment preference.

Another highlighting advantage is the avoidance of Soft H/O, which means an evolution towards PS dominated system. Such a system can use VoIP for voice data. The User Plane and the Intra-cell Control Plane can be moved to the base station for the unloading and the simplification of the RNC. Further on, the smart base stations can have a direct connection to the Core Network and an interconnection between the smart base stations for call context transfer. Together with a new inter-cell Control Plane Server in the Core Network area the operational demands of the RNC will be decreased.

Figure 1 shows the inter-relationship between the most important entities of the radio network: the access manager and the smart base station, where in the figure, the RNC is removed from the UTRAN. Instead, most conventional functions responsible by the RNC are taken over by the smart base station and the Access Manager, as is a typical experience of function reallocation in the radio subsystem.

The smart base station can take over some control and user plane functions. Some RNC functionalities are possible to be reallocated at the base station, e.g.:

- Cell Control
- Dedicated Channels Processing
- Common / Shared Channels Processing
- Simple radio resource management
- Mobility Control

3.1 Vertical Interface (through hierarchy levels)

The Access Manager is a stand-alone device or a part of the SGSN. This Manager is the anchor point towards any kind of Core Network. In present UTRAN architectures the anchor towards the Core Network is the RNC. In addition, the present RNC basically forwards data from/ to the Core Network. This part will be taking over by the Access Manager, which will now manage the dataflow from/ to the core network, e.g. User plane data/ RANAP (*Radio Access Network Application Part*)/RNSAP (*Radio Network System Application Part*).

Secondly the Access Manager may contain some former RNC area-related functions, for instance Multi-Cell RRM/ Paging.

3.2 Horizontal Interface (among base station peers)

For the architecture an interface between the smart base stations can be deployed. This interface supports the user mobility by the combined relocation and cell change. In addition, this interface has mainly the control plane. The advantages for the relocation of the control plane to the smart base stations are:

- No traffic drifting -> tromboning effect is avoided, where the tromboning effect blocks value added services, e.g., the transcoder free operator (TFO) for software download multiplexed with voice service.
- For real time traffic -> RLC context transfer. By transferring functions located in the RNC to the smart base station, the efficiency (reaction speed) of the scheduler improves. The same rule can be found in Section 2.2.

This new inter-base station Interface based on a subset of RNSAP will be used basically for context transfer during relocation and cell change.

For the real time traffic the interface between the base stations must be optimised in terms of:

- Transfer RLC/ MAC buffers, this will be very much helpful for TCP/IP performance
- Reduction of disruption time during relocation and cell change

4. FUNCTION REALLOCATION IN THE O&M SUBSYSTEM

To design architecture enabling reconfigurability and function reallocation, one of the most important principles is separation of concerns. The principles should be considered for all parts of the system.

Well concern-separated system has next advantages. First, high modularity can be achieved by designing a module which is separated from other concerns. Second, it facilitates changeability of the system by minimizing influence caused by changing. Therefore reusability can be easily done for the future.

The following two major separations of concerns are required for the reconfigurable OMC subsystem. The first separation is between reconfiguration mechanism and functional changes and the second separation is between different applications which don't have any relations.

Current radio OMC subsystem is partly considering separation between reconfiguration management and functional reconfiguration. Separation between management system and network element can be an example. In current system decision of reconfiguration is taken care of the network management system and functional reconfiguration is executed at the network elements.

This separation, though, doesn't provide the real advantages of the principle for the reconfigurable network. OMC is tightly coupled with a certain network element. When OMC needs to change its function the network element is influenced and vice versa. Separation between management system and the function reallocation among network element is therefore a requirement for the reconfigurable system.

There are several use cases for reconfigurable radio network. According to the use cases mobile network contains many functional parts such as antenna tilting, coloured power control etc. Except for some types of configuration are common for several different functions, there are still considerable types of configuration or parameters are only related to a certain function or reconfigurable mechanism. To minimize those unnecessary influences the reconfiguration mechanism for each function should be separated respectively. For the shared configuration inventing protocols for exchanging information between different concerns can solve the problems.

The problem arises when different management technologies are used for the same networked system: Interoperability among all different management models involved is necessary to provide a unified view of the whole managed system. However, only syntactic translations among management languages have been applied to date [2].

Among many different types of network elements, some with very high management complexity are generally supported with unique vendor specific management systems with very low interoperability. Currently most of interfaces are closed, even in same vendor's management products. Interfaces are expensive parts in radio network management and interfaces with low level of openness severely impact on development lead-time for the introduction of any system, application component or service. Many second-generation mobile network physical management entities have vendor controlled system/subsystem boundary descriptions that are not disclosed to the public or are unique to this single supplier. Such interfaces will not fulfil the basic requirements of reconfigurable network. Closed interfaces can only be used as internal interfaces where no information has to be shared to other physical management entities. By designing commonly used and widely supported interface standards interoperability, reusability, reconfigurable performance will be highly improved.

Figure 3 shows the overall architecture of the reconfigurable radio network recommended here. In this architecture radio system is divided into several parts, called *Adaptation Unit (AU)*, according to its reconfigurable functionalities, which is to split complexity to manageable domains. *Adaptation Unit* plays a role of a unit for adaptation as the name says.

An *AU* consists of two levels; one is the *Adaptation Level* and another is *Functional Level*. The *Adaptation Level* is in charge of adaptation and management mechanisms. This level is constructed with multi-agent system which has its own ontology and keeps the information on configuration and adaptation strategies of the unit. Even though every adaptation level is owned by its *Adaptation Unit*, the mechanisms and inner architecture can be reused for other *Adaptation Units*. The *Functional Level* consists of functional components for the system functions. By constructing functional parts as a component based system reconfiguration can be easily done at run time. Functional level is specific to a certain adaptation unit. Protocols for interoperability between different *Adaptation Units* and different operators should be introduced as well.

By realizing self-adaptive ability in radio network architecture we can expect the following positive effects.

- To reorganize radio network management architecture for the future work facilitating to add the continuously changed requirements, in addition for system to adapt itself to their changing environments

- To design software modules representing OMC functions as adaptive software system facilitating evolution for the future radio network

- To save throughput requirements for O&M signalling flow such as the Iub interface

5. CONCLUSIONS AND DISCUSSIONS

The advantage of the Smart base station overlay is that all functions of the included in this smart base station imply less network elements. For that, the base station needs a direct CN – base station connectivity. By the introduction of the IP interface the packet over IP is now possible. The Packet over IP supports all QoS classes, including VOIP. The introduction of mobile IP supports all needed QoS classes too.

The Access Manager as a possible new part of the architecture including the Multi-cell RRM and CAC tasks in the Core Network (e.g. integrated in SGSN) or close to the Core Network. All these properties of the smart base station and the Access Manager supersede the RNC. With the replacement of the RNC, the network architecture will be simplified and cheaper.

In addition, in the rollout of the smart base station, with the granularly growth of elastic traffic, which are mostly IP based, more traffic will be allocated into the segments of the smart base station branch. With the deployment of more IP based real time services, e.g. VoIP service, much conventional transport, e.g. circuit switched service through legacy base station, will be replaced by the packet oriented network elements.

With complex reconfiguration supporting various function re-allocations, the basic on-the-fly setting of radio parameters and implementation parameters needs to be supported by the network. By changing implementation parameters such as the antenna tilt and the maximum transmission power, the portion of power reserved for a particular service or even the complete reconfiguration between RATs needs an intelligent O&M system to monitor, observe, reason, optimize, decide and execute reconfiguration functionalities.

According to the ITU-TMN reference model [3], the management architecture needs to assist operators in managing their integrated networks taking principles like *Simplicity*, *Functionality, Integrity, Heterogeneity* and *Connectivity* into account. Although 3GPP accordingly specifies UTRAN O&M subsystem [4] including *procedures for Network expansion*, *Cellular network configuration procedure*, *Remote software update procedure*, *Network optimization procedure*, *Network monitoring* and *fault management procedures* (e.g. alarm and event notifications), the existing O&M subsystem and its software implementation seem to be '*out-paced*' compared to the future network growth stimulated by reconfigurability. In fact, the need for an O&M evolution has already been identified by the TeleManagement forum [5].

In conjunction with our network planning and management research activity, we propose the following options of a suitable O&M system for the reconfigurable system.

- Reduce the responsibilities of LMT (Local Maintenance Terminal) and accordingly increase the functionalities of the relevant OMC (O&M commander)
- Increase Software reusability including the reuse the same software module for different technologies (technology neutral [5]) and the reuse of optimisation modules, i.e., the partial integration of the planning and management tool-set in the radio commander is necessary
- Open interfaces, e.g., the north-bound interface allowing multi-vendor/multi-technology
- Adding self-learning software agents into some management entities will encounter frequently changing radio environment. This option reduces the load of the existing O&M interfaces

In order to support the complex resource management and element management, efficient network management architecture with optional modifications to the current standards is needed.

6. ACKNOWLEDGEMENT

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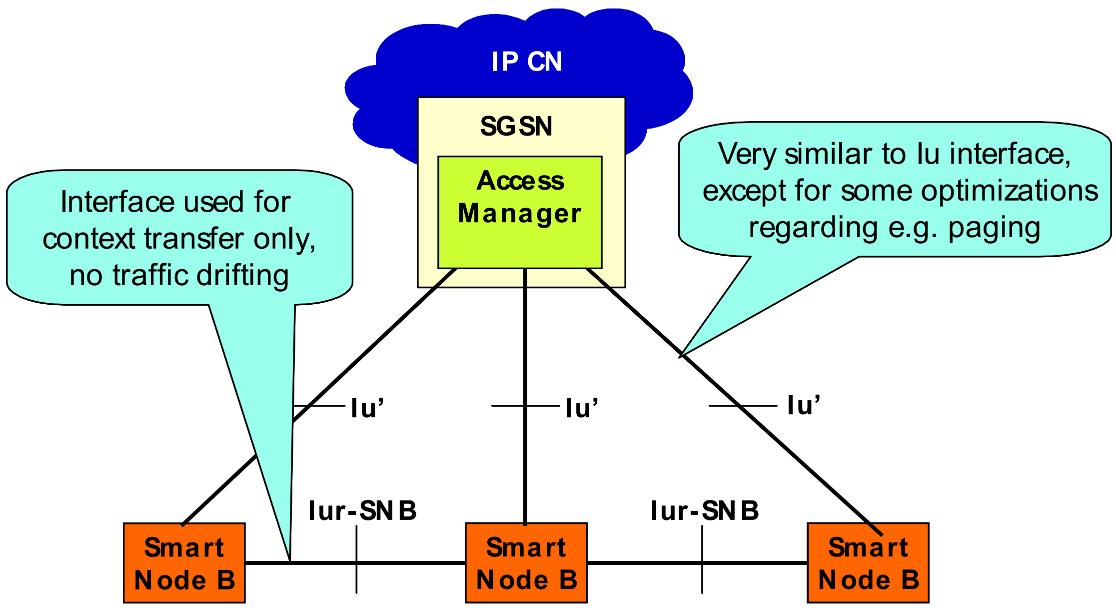

Figure 1: Access Manager in an IP CN (an Example)

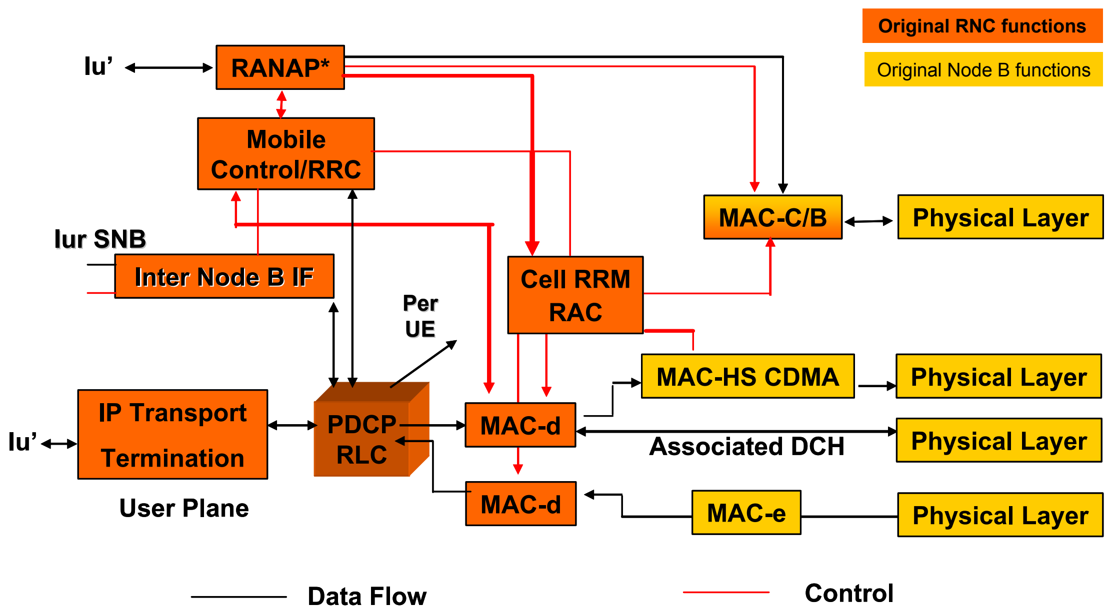

Figure 2: Possible Protocol Architecture at the Overlaid Base Station

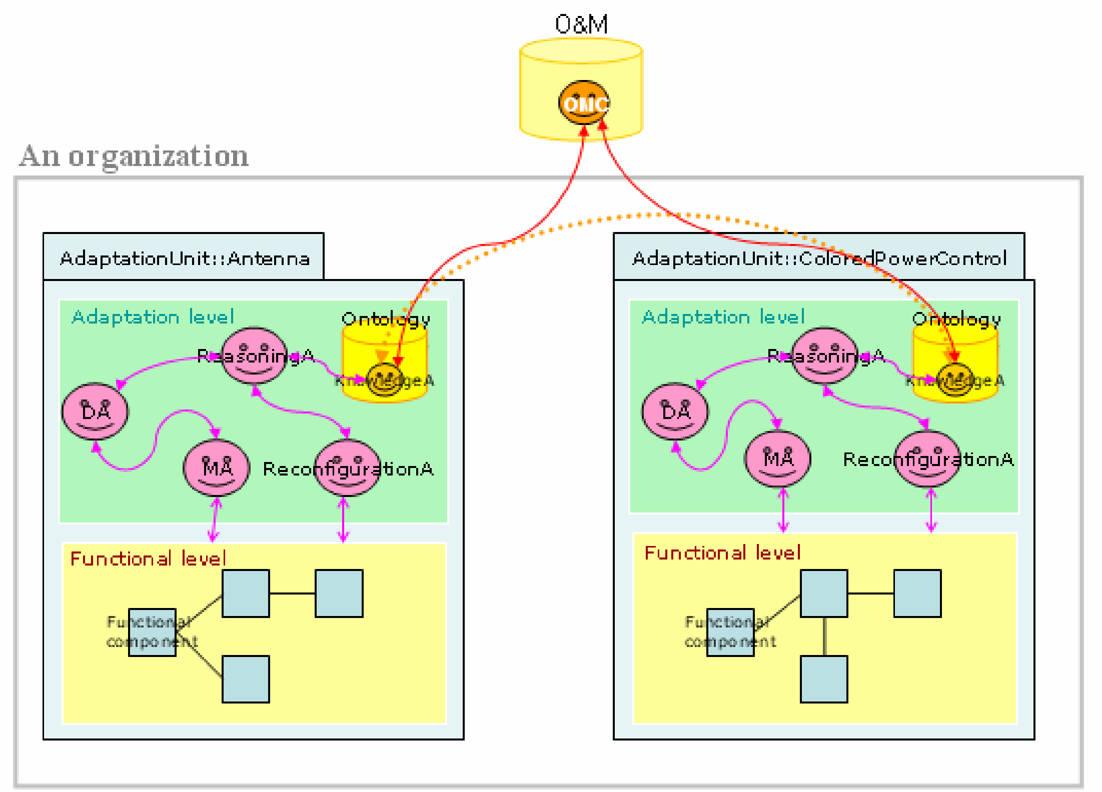

Figure 3: The overall architecture for an organization